Supplemental Document 7

Protocol Development Summaries

The protocol development summaries (PDSs) presented here detail the status of protocols that we intend to implement within the next six years. These protocols are in various stages of completion, a point that is reflected by the varying degrees of detail in the summaries. Further, inclusion of summaries for these protocols does not preclude development and implementation of additional protocols within the timeframe.

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PROTOCOL DEVELOPMENT SUMMARY – WATER QUALITY OF LARGE RIVERS

Protocol: Monitoring water quality in large rivers of national park units of the Great Lakes Inventory and Monitoring Network [short name: large rivers]

Parks Where Protocol will be Implemented: MISS, SACN

Justification/Issues Being Addressed:

Large temperate rivers around the world, including the river-based national park units in the Great Lakes Network (GLKN), have been historically affected by human activities and face an uncertain future in which water quality may be further threatened by climate change, urban development, agriculture, exotic species, recreation, and transportation uses (Meybeck and Helmer 1989, Zhang et al. 1999). In addition, large rivers can transfer pollutants from land to sea. For example, agricultural nitrogen in the Mississippi River is causing hypoxia in the Gulf of Mexico (Burkart and James 1999).

Recognizing the importance of water quality and the variety of looming threats, the GLKN ranked water quality among the highest of Vital Signs to be monitored (Route 2004). A large-rivers conceptual model (Lubinski 2004) identified key attributes as water flow and basic water quality variables, including nutrients, dissolved oxygen, sediment, and temperature. These variables will be the focus of the large rivers protocol.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Our overall goal is to develop a protocol for monitoring water quality in rivers and streams comparable to state and national monitoring efforts that will allow detection of trends. Some of the specific questions we will address in this protocol are:

- What are the current status and trends (magnitude and direction of change) in systematic flow regime in the main stem of the St. Croix and Upper Mississippi Rivers and targeted tributaries?
- What are the current status and trends (magnitude and direction of change) in select water quality parameters, including temperature, pH, specific conductance, dissolved oxygen, water clarity, sediment loads, alkalinity, major ions, and nutrients, in the main stem of the St. Croix and Upper Mississippi Rivers and targeted tributaries?
- Are changes in water quality parameters associated with other Vital Signs (e.g., aquatic biotic communities (including exotic species), land cover/use, weather/climate, or atmospheric deposition)?

Flow is the key parameter for physical conditions in rivers; it is needed to interpret concentration data and calculate water quality loadings. It is singled out here because flow measurement is operationally different from other water quality monitoring parameters. Flow regimes have been historically altered by land-use changes and may continue to be impacted by shifting agricultural practices, expanding urbanization, and climate change driven by greenhouse warming (Lenz 2004).

Basic Approach:

This program is designed to monitor the water quality of the Mississippi, St. Croix, and Namekagon Rivers within the boundaries of MISS and SACN. The practical strengths of the USGS – National Water Quality Assessment Program (NAWQA; Gilliom et al. 1995) and EPA – Environmental Monitoring and Assessment Program (EMAP; McDonald et al. 2002) methods will be incorporated into the GLKN large river water quality program. Unlike the USGS and EPA study units, these NPS parks do not include the entire watershed but rather are linear features containing sections of the mainstem of the rivers and very little of the riparian lands. Only the mouths of tributaries fall within park boundaries. Geographic stratification of the population by subwatersheds and stream-order weighting does not apply. Random site selection along the mainstem using statistical methods (e.g., generalized random-tessellation stratified; Stevens and Olsen 2004) can ensure scientifically valid assessments of mainstem river water quality. However, tributaries often influence water quality within the mainstem (e.g., the influence of the Minnesota River on the Upper Mississippi), and it will be important to monitor the contributions of tributaries. In addition, particular mainstem locations may be deemed important monitoring sites. Therefore, this program will include both randomly-selected sites and nonrandomly-selected sites.

The optimal number of randomly-selected sites has been determined through power analysis of existing data; the selection of nonrandom sites is based on criteria of the St. Croix Watershed Basin Team and the GLKN budget.

The NPS -Water Resources Division (WRD) mandated that all water quality monitoring programs include a core suite of parameters, specifically, pH, dissolved oxygen, temperature, specific conductance, and flow. Our monitoring of large rivers will include these basic parameters along with measures of major ions, alkalinity, clarity, turbidity, suspended solids, and nutrients.

Principal Investigators and NPS Lead:

The protocol is being developed through a cooperative task agreement with the St. Croix Watershed Research Station (SCWRS), 16910 152nd St. N., Marine on St. Croix, Minnesota 55047, (651) 433-5953. Principal investigators, Suzanne Magdalene and Daniel Engstrom (both of SCWRS), are working with Joan Elias (GLKN), Ashland, Wisconsin, 715-682-0631, to develop the protocol.

Development Schedule, Budget, and Expected Interim Products:

This protocol has been peer-reviewed and is nearly complete. Pilot testing began in 2006 at MISS.

In a project related to this protocol, the Network has an agreement with SCWRS to establish sampling sites on the St. Croix and Namekagon Rivers. As part of this project, SCWRS staff will train the GLKN aquatic ecologist in establishment of sites, including the determination of discharge rating curves. The methods for establishing sites on these large rivers will be transferable to wadeable streams, another protocol under development.

Literature Cited:

Burkart, M. R., and D. E. James. 1999. Agricultural-nitrogen contributions to hypoxia in the Gulf of Mexico. Journal of Environmental Quality **28**:850-859.

Gilliom, R. J., Alley, W. M., and Gurtz, M. E. 1995. Design of the National Water-Quality Assessment Program: Occurrence and Distribution of Water-Quality Conditions. United States Geological Survey Circular 1112.

Lenz, B. 2004. Analysis of streamflow and water-quality data at two long-term monitoring sites on the St. Croix River, Wisconsin and Minnesota. Water-Resources Investigations Report 03-4334, U.S. Geological Survey, Madison, Wisconsin.

Lubinski, K.S. 2004. Large river conceptual model. *In* S. Gucciardo, B. Route, and J. Elias, editors. Conceptual Ecosystem Models for the Great Lakes Network. GLKN/2004/04.

McDonald, M. E., S. Paulsen, R. Blair, J. Dlugosz, S. Hale, S. Hedtk, D. Heggem, L. Jackson, K. B. Jones, B. Levinson, A. Olsen, J. Stoddard, K. Summers, and G. Veith. 2002. Research strategy of the Environmental Monitoring and Assessment Program. EPA 620/R-02/002. Meybeck, M., and R. Helmer. 1989. The quality of rivers: From pristine stage to global pollution. Palaeogeography, Palaeoclimatology, and Palaeoecology **75**:283-309.

Route, B. 2004. Process and results of selecting and prioritizing Vital Signs for the Great Lakes Network. U.S. National Park Service, Great Lakes Inventory and Monitoring Network. Technical Report GLKN/2004/05.

Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association **99**:262-278.

Zhang, J., H. T. Chen, Z. F. Zhang, S. M. Liu, and Y. Wu. 1999. Human impacts on the large world rivers: Would the Changjiang (Yangtze) River be an illustration? Global Biogeochemical Cycles **13**:1099-1105.

PROTOCOL DEVELOPMENT SUMMARY – WATER QUALITY OF INLAND LAKES

Protocol: Water quality monitoring protocol for inland lakes of the Great Lakes Inventory and Monitoring Network [short name: inland lakes]

Parks Where Protocol will be Implemented: APIS, INDU, ISRO, PIRO, SLBE, VOYA

Justification/Issues Being Addressed:

Inland lakes are important and valuable resources at six GLKN parks and are used extensively by visitors for fishing, boating, swimming, and other recreational activities. Inland lakes are prevalent in the Network parks, and the preservation of lake water quality and quantity is of utmost importance to park managers, researchers, and the general public.

Water quality is generally high throughout GLKN parks, though threats exist from atmospheric deposition, urban and agricultural runoff, wastewater discharges and seepage from septic systems, recreational use, and other anthropogenic impacts. Network lakes listed as impaired under Section 303(d) of the Clean Water Act are only so designated because of fish consumption advisories (Ledder 2003). All waterbodies within INDU, ISRO, PIRO, and SLBE are designated Outstanding State Resource Waters, and all those in VOYA are designated Outstanding Resource Waters. Waterbodies within APIS have no legal designation, although the waters of Lake Superior are designated as federal Outstanding Resource Waters (Ledder 2003).

Monitoring basic water quality ranked among the highest of the Network's Vital Signs (Route 2004), although it was recognized that these measurements were less diagnostic of water quality degradation than biotic communities and other water quality variables, such as nutrient concentrations. The effects of inputs of excess nutrients, contaminants from atmospheric fallout and surface runoff, and other stressors on the chemical and biological functions of lakes are key issues of concern. We will monitor water quality parameters that will provide data for a thorough understanding of changes in lakes over time.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Our overall goal is to develop a protocol for monitoring water quality in lakes comparable to state and national monitoring efforts that will allow detection of trends. We will continue to refine and add to the questions below and will develop additional, related protocols for select aquatic biota. Some of the specific questions we will address in this protocol are:

- What are the current status and trends (magnitude and direction of change) in select water quality parameters, such as temperature, pH, specific conductance, dissolved oxygen, water clarity, alkalinity, major ions, and nutrients, in individual lakes?
- What are the current status and trends (magnitude and direction of change) in select water quality parameters of lakes aggregated for each park unit? How are the lakes of each park behaving overall?

- What are the current status and trends (magnitude and direction of change) in select water quality parameters of the lakes across GLKN parks? Is the behavior of lakes within GLKN parks similar to lakes across the larger region as a whole?
- Are changes in water quality parameters associated with other Vital Signs, such as measures of biotic communities, land cover/use, weather/climate, or atmospheric deposition?

Basic Approach:

The sample design for the inland lakes protocol will consist of index lakes, with lake selection based on a combination of historical data, information on lake type (e.g., Carlisle 2002, Schupp 1992), park management concerns, spatial distribution, and accessibility. The frequency of sampling (three times during the open-water season), sample locations (single site per lake, at the deep hole), and parameters to be measured allow integration and comparisons with data collected by state and other agencies. We defined lakes as waterbodies with a surface area > 1 ha and a maximum depth of > 1 m, which was drawn from the federal EPA-EMAP program (Baker et al. 1997), and generally fits the definitions used in the upper Great Lakes states. Every selected lake will be sampled annually, according to recommendations by peer reviewers of the first draft of the protocol narrative.

Accessibility of lakes is a critical logistical constraint at both VOYA and ISRO, which have 299 and 87 lakes, respectively, that meet the lake criteria. Most of these lakes are unnamed, or are transitory beaver ponds (265 in VOYA and 45 in ISRO), are often shallow across much of their area, and would require two or more days of off-trail, back-country travel to access. We decided to restrict the sample domain to those lakes that do not pose significant accessibility or safety issues

This protocol addresses monitoring of inland lakes to assess change in basic limnological parameters. We will measure the suite of parameters mandated by the NPS (National Park Service 2002; temperature, pH, specific conductance, dissolved oxygen, and flow/water level). We added a measure of clarity (Secchi depth or transparency tube depth) to this core suite. In addition to this core suite of parameters, we will measure major ions, alkalinity, dissolved organic carbon, chlorophyll *a*, and nutrients.

The parameters to be measured under this protocol include those that may respond to atmospheric deposition, runoff, land cover/land use change, distance to roads, recreational activities, climate change, and/or introduction of exotic species. It will be important to examine water quality changes in light of land use practices throughout the watershed in which each waterbody occurs. Concomitant monitoring of atmospheric deposition, range and abundance of aquatic nuisance species, various aquatic biotic communities, and bioaccumulation of contaminants may help to explain or verify changes in basic water quality parameters.

Principal Investigators and NPS Lead:

The first draft of the protocol was developed through a cooperative task agreement with the University of Minnesota-Duluth, Natural Resources Research Institute (5013 Miller Trunk Highway, Duluth, Minnesota, 55811, 218-720-4294). Principal investigators, Rich Axler and George Host (both of NRRI), worked with Joan

Elias (GLKN), Ashland, Wisconsin, 715-682-0631, to develop this draft. The protocol will be completed by J. Elias, with additional cooperators, if needed, to be determined.

Development Schedule, Budget, and Expected Interim Products:

The first draft of this protocol has been peer reviewed and is under revision. Pilot testing began at VOYA and INDU in 2006.

Literature Cited:

Baker, J. R., D. V. Peck and D. W. Sutton, editors. 1997. Environmental Monitoring and Assessment Program (EMAP) surface waters: Field operations manual for lakes. EPA/620/R-97/001. U.S. Environmental Protection Agency, Washington D.C.

Carlisle, D. M. 2002. Summary of recent analyses of Isle Royale aquatic resources. Report to Isle Royale Natural Resources Specialist. Isle Royale National park, Houghton, Michigan.

Ledder, T. 2003. Water resource information and assessment report for the Great Lakes Inventory and Monitoring Network, Ashland, Wisconsin. Great Lakes Technical Report: GLKN/2003/05.

National Park Service. 2002. Recommendations for core water quality monitoring parameters and other key elements of the NPS Vital signs program. National Park Service Freshwater Workgroup Subcommittee, August 15, 2002, Fort Collins, Colorado.

Route, B. 2004. Process and results of choosing and prioritizing Vital Signs for the Great Lakes Inventory and Monitoring Network. National Park Service, Great Lakes Inventory and Monitoring Network, Ashland, Wisconsin. Great Lakes Network Technical Report: GLKN/2004/05.

Schupp, D. H. 1992. An ecological classification of Minnesota lakes with associated fish communities. Minnesota Department of Natural Resources Investigational Report 417.

PROTOCOL DEVELOPMENT SUMMARY – BIOACCUMULATIVE CONTAMINANTS

Protocol: Bioaccumulative contaminants [short name – contaminants]

Parks where Protocol will be Implemented: This protocol will be piloted at APIS, MISS, ISRO, SACN, SLBE, PIRO, and VOYA and will eventually be implemented in all parks in the Great Lakes Network (APIS, GRPO, INDU, ISRO, MISS, PIRO, SACN, SLBE, and VOYA).

Justification/Issues being addressed:

The nine Great Lakes Network parks are within a region exposed to a high number of environmental contaminants (Rattner et al. 2005). The chemicals of greatest risk to wildlife and humans are those that bioaccumulate and are generally known at Bioaccumulative Compounds of Concern (BCCs). These BCCs enter parks by point and non-point sources through atmospheric deposition, biotic processes, and through water-borne routes. In some cases they are slowly released from sediments where they have been tied up for years (e.g., Fox River and Green Bay, Wisconsin). Biosentinel species, those that accumulate BCCs and/or exhibit reproductive effects as a consequence of exposure, have been used in many regions of the world to monitor ecosystem quality.

Ample historical evidence exists linking reproductive impairment and developmental deformities in wildlife with contaminants in the environment (Wiemeyer et al. 1984). The Great Lakes region, primarily with the lead of the International Joint Commission's (IJC), has developed criteria for both defining and identifying these relationships (Fox et al. 1991).

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Our goal is to provide park managers with knowledge on the trends and ecological effects of targeted, human-made toxic chemicals that are known to bioaccumulate in aquatic systems of parks in the Great Lakes Network. While it is important to acknowledge toxics and their effects on terrestrial systems, contaminants that are deposited on land will accumulate quickly in waterbodies from rain and snow runoff. Hence, we will focus on aquatic systems to increase sampling efficiency.

Our initial focus for protocol development will be on the bald eagle (*Haliaeetus leucocephalus*) and the herring gull (*Larus argentatus*) as biosentinal species for monitoring. We will use these species to collect tissue samples indicative of toxics in the environment and to assess reproductive success.

Specifically, the objectives are to:

1. Monitor trends in targeted environmental contaminants that bioaccumulate in tissues of selected indicator species;
2. Measure trends in reproductive outcomes, such as measures of success and incidence of deformities related to contaminants in selected indicator species, including reproduction and survival;
3. Archive tissue samples from selected indicator species and periodically investigate the concentrations of new and emerging toxicants.

The protocol will be developed in two phases (see development schedule below). During the first phase we will concentrate on the following monitoring questions:

1) What is the direction and magnitude of change in the concentrations of DDT, PCBs, PBDE, and PFOS in plasma, and mercury and lead in feathers, from nestling bald eagles in APIS, MISS, PIRO, ISRO, SACN, SLBE, and VOYA?
2) What is the incidence of developmental deformities observed in live and dead nestlings of bald eagles at APIS, MISS, PIRO, ISRO, SACN, SLBE, and VOYA?
3) What is the direction and magnitude of change in the number of young produced per occupied bald eagle nest at APIS, MISS, PIRO, ISRO, SACN, SLBE, and VOYA?
4) What is the direction and magnitude of change in the concentrations of PCBs, dioxin, organochlorine pesticides, PBDEs, and mercury in fresh eggs of herring gulls in VOYA, ISRO, APIS, and SLBE?

During the second phase we will address mercury more specifically because of its prevalence in several Network parks and concomitant fish consumption advisories. At that time we will add monitoring questions specifically for mercury. In the second phase we will include INDU and GRPO.

Basic Approach:

Our sampling design builds upon ongoing monitoring programs in the Great Lakes region. For GLKN to begin an entirely new monitoring program for bioaccumulative contaminants would be cost-prohibitive and duplicative. The bald eagle has been used to monitor concentrations of persistent toxic chemicals in the aquatic environment of the upper Midwest for over 20 years (Bowerman et al. 2003). The bald eagle was selected as the primary avian sentinel species by the Michigan Biosentinel Program, which has monitored the concentrations of organochlorine pesticides and PCBs in nestling eagle blood since 1986 (Roe 2004). A long-term trends analysis of these compounds coupled to a long-term database on productivity in Michigan eagles since 1961 enable analysis at many geographic scales. We will adopt the methods of the Michigan Biosentinel Program (Roe et al. 2004) and those used by the Wisconsin Department of Natural Resources (Meyer et al. 1993) for collecting and analyzing blood serum and feathers from bald eagle nestlings. We will summarize and interpret the results for the Network parks.

Since 1974, the Canadian Wildlife Service (CWS) has been collecting herring gull eggs from gull colonies across the Great Lakes. This is one of the longest running datasets on toxics in wildlife in the region (Weseloh et al. 1991). We will adopt their methods and provide herring gull eggs to them for analysis at the University of Windsor in Canada. We will then summarize and interpret the results for the Network parks.

The methods will include collecting tissue samples from both species - blood and feathers from bald eagles, and eggs from herring gulls - and sending these samples to analytical labs to determine the concentrations of target contaminants. The protocols will also include estimations of abundance, reproductive success, and documentation of tumors and other deformities.

Site Selection

Sampling locations will be determined by the location of nesting bald eagles and the location of herring gull colonies. The number of bald eagle samples at each park will be determined by how many nests have produced young, the accessibility to each nest, and safety (e.g., weather and unsafe nest trees). If sample size is low, we may also sample on lands adjacent to parks if the data would be instructive for park managers (i.e., as a comparison or to increase sample size for a geographic region or watershed) and if access is granted by the owner. See also the discussion on sample size below.

Herring gull colonies are established at two sites in APIS, one site at VOYA, two at ISRO, and one at SLBE. Each of these colonies has sufficient numbers of gulls for collecting egg samples as per the CWS protocol. However, the CWS limits its sampling to a single colony when two or more colonies are within 40 miles of each other. Hence we will sample from only one colony per park. For ISRO the site has already been selected by CWS which is included in their long-term monitoring. Of the two colonies available at APIS, park management has denied access to one colony due to potential disruption of cormorants nesting there. Thus all sites have been either pre-selected (ISRO and APIS), or are the only available colony for sampling (VOYA and SLBE).

Sampling Frequency and Sample Size

Bald eagles

For the first two years we will collect blood and feather samples at each park from up to two nestlings from each bald eagle nest with young, with due consideration for safety. We will also sample from nests adjacent to parks when sample size is very low ($n < 10$) and access is granted by the land owner. This additional sampling will occur only if the nest(s) are representative of the park's waters. A nest will be considered representative if a portion of the foraging area is in the park or when the waterbody being used by the eagles for foraging is shared and within one-half mile of the park boundary.

The number of bald eagle pairs that defend territories varies between parks and within years depending on habitat availability and the health of the regional eagle population. The number of young produced can be influenced by natural and anthropogenic stressors such as weather, prey availability, disturbance, and contamination. Thus the number of blood and feather samples each year will vary among parks and between years. Even with small sample sizes, each nestling is effectively integrating contaminants from prey in the local area where adults forage to feed the young. Hence the eagles are 'sampling' the environment for us and our results will indicate the availability of contaminants to organisms in and adjacent to the parks.

For each nestling we sample, we will take 10 to 11 cc of blood, which will result in about five to six cc of serum available for lab analysis. Initially, we will analyze serum from only one nestling per nest as the second nestling would not constitute an independent sample. Blood samples from the second nestling will be archived for future use in tracing first occurrence of new and emerging contaminants or as a back-up if the original sample is compromised. They may also be used to corroborate questionable findings. In addition, although genetic testing is not a part of this sampling protocol, the archived samples may prove invaluable in the future for assessing whether higher levels of chemical contamination or other stressors are correlated with lower survival in adult bald eagles. Similar to blood samples, feathers from only one nestling per nest will be initially analyzed for contaminants. We will select the same nestling that is being used for blood contaminants for comparison purposes.

<u>Herring gulls</u>

We will sample one colony in each of four parks. All herring gull egg collection methods and sample sizes will be identical to those of the Canadian Wildlife Service. All eggs in 30 randomly selected three-egg clutches will be measured (length and width). Thirteen of these 30 clutches will be selected at random and one egg randomly collected from each. Hence 13 eggs will be collected from each gull colony in the four parks where they exists. Eggs will be collected every year from each colony, but lab analysis for toxics will be done on a five-year rotation. This entails analysis of 10-egg pooled samples for four years and 10 individual eggs one year to determine within-colony variance (Weseloh et al. 1991).

Level of Change that can be Detected

Roe (2004) tested a similar biosentinel program on bald eagles in Michigan after four years of collecting nestling blood samples at six geographic scales. The data were sufficient to determine differences in target contaminants among geographic areas with an alpha of 0.05 and power (1 - beta) of 0.8 among units. They also tested for changes in p,p'-DDE and total PCB concentrations of 10% over a 10 year period with alpha of 0.05 and power of 0.8. In all cases and in all six geographic scales (from the state of Michigan down to individual watersheds) the data met the Great Lakes Network criteria of being able to detect a change of $\geq$ 20% in $\leq$ 10 years with alpha 0.10 and power 0.8. The only exceptions were watersheds in which nest sites occurred on both inland lakes and Great Lakes. Roe (2004) also established sample sizes necessary to meet these alpha and beta criteria for determining trends and differences among geographic units.

Principal Investigators and NPS Lead:

The principal investigator developing phase 1 of the protocol, which includes the narrative and standard operating procedures (SOPs) for bald eagles and herring gulls is Dr. Bill Bowerman, Clemson University. In FY2007, Dr. Jim Wiener, University of Wisconsin, La Crosse, will join the team and add SOPs for species specific to mercury. The NPS lead for this protocol is Bill Route, terrestrial ecologist/network coordinator.

Development Schedule, Budget, and Expected Interim Products:

A draft of the protocol was submitted by Dr. Bowerman in May 2005. This draft was subsequently revised by NPS lead Bill Route who obtained in-house peer review in winter 2005-06. These comments were incorporated and pilot field work occurred in the summer of 2006. The protocol has been further refined, incorporating knowledge on logistics and costs experienced from the 2006 pilot work, and has now been sent out for external review. We expect external review comments in December 2006 and revisions will be incorporated prior to the 2007 field season.

Dr. Wiener will begin adding components specifically related to mercury in FY2007. We expect this new component to be ready for implementation in 2007 or 2008.

Literature Cited:

Bowerman W. W., D. A. Best, J. P. Giesy, M. C. Shieldcastle, M. W. Meyer, S. Postupalsky, and J. G. Sikarskie. 2003. Associations between regional differences in polychlorinated biphenyls and dichlorodiphenyldichloroethylene in blood of nestling bald eagles and reproductive productivity. Environmental Toxicology and Chemistry **22**:371-376.

Fox, G. A., D. V. Weseloh, T. J. Kubiak, and T. C. Erdman. 1991. Reproductive outcomes in colonial fish-eating birds: A biomarker for developmental toxicants in Great Lakes food chains. I. Historical and ecotoxicological perspectives. Journal of Great Lakes Research **17**:153-157.

Nisbet, I. C. T. 1998. Trends in concentrations and effects of persistent toxic contaminants in the Great Lakes: Their significance for inferring cause-effect relationships and validating management actions. Environmental Monitoring and Assessment **53**:3-15.

Rattner, B. A., K. M. Eisenreich, N. H. Golden, M. A. McKernan, R. L. Hothern, and T. W. Custer. 2005. Retrospective ecotoxicological data and current information needs for terrestrial vertebrates residing in coastal habitat of the United States. Archives of Environmental Contamination and Toxicology **49**:257-265.

Roe, A. S. 2004. Ph.D. dissertation, Clemson University, Clemson, South Carolina. Unpublished.

Weseloh, D. V., S. M. Temple, and M. Gilbertson. 1983. Double-crested cormorants of the Great Lakes: Egg-laying parameters, reproductive failure, and contaminant residues in eggs, Lake Huron 1972-1973. Canadian Journal of Zoology **61**:427-436.

Weseloh, D. V., C. A. Bishop, R. J. Norstrom, and G. A. Fox. 1991. Monitoring levels and effects of contaminants in herring gull eggs on the Great Lakes, 1974-1990. Pages 29-31 *in* Abstracts from the papers given at the Cause-Effects Linkages II Symposium. September 27-28. Lansing, Michigan: Michigan Audubon Society.

Wiemeyer S. N., T. J. Lamont, C. M. Bunck, C. R. Sindelar, F. J. Gramlich, J. D. Fraser, M. A. Byrd. 1984. Organochlorine pesticide, polychlorobiphenyl, and mercury residues in bald eagle eggs--1969-1979--and their relationships to shell thinning and reproduction. Archives of Environmental Contamination and Toxicology **13**:529-549.

PROTOCOL DEVELOPMENT SUMMARY – AMPHIBIANS

Protocol: Long-term monitoring of amphibians in the Great Lakes Network [short name: Amphibians]

Parks Where Protocol will be Implemented: APIS, GRPO, INDU, ISRO, MISS, PIRO, SACN, SLBE, VOYA

Justification/Issues Being Addressed: Amphibians were ranked the eleventh highest priority Vital Sign across park units of the Great Lakes Network. The reasons include:

- Declines of populations of amphibians are among the most prominent global issues in conservation biology (Lannoo 2005).
- Amphibians generally are sensitive to changes in environmental factors, including temperature, precipitation, humidity, hydrology, land cover, nutrients, toxicants, and exotic species, among others, and are highly linked in food webs to many other ecosystem components.
- Many species of amphibians live in both terrestrial and aquatic habitats. Thus, their fitness reflects environmental conditions across both types of habitats.
- Various life stages of amphibians typically allow for rigorous sampling designs for monitoring. This same quality is invaluable for conducting manipulative experiments when further studies are necessary to establish the causes and effects of any declines that are observed.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Objective 1: Assess potential trends in site occupancy

a) Annually determine the presence of several wetland-breeding species at each of many predetermined locations throughout the breeding season in each park, including species that breed during early, middle, and later periods of the summer season.

b) Quantify occupancy of breeding sites for targeted species across parks each year (MacKenzie et al. 2002, MacKenzie et al. 2003).

c) Assess the site occupancy over time to determine if the distribution or number of breeding subpopulations of any monitored species changed significantly and compare these results with results from other national and state programs.

<u>Objective 1 Questions</u>:

Do the distributions of monitored species agree with predictions for each park, based upon known historical distributions?

Are there any trends in occupancy for monitored species across parks that indicate potential changes in environmental conditions?

How do the magnitudes and directions of any changes in occupancy of targeted species compare with results from other regional and national surveys?

How often are species not detected at a site until the second visit (within each season)? Until the third visit (within each season)?

Objective 2: Correlate trends in distribution to covariates likely to be important

a) Use portable meters during surveys, nearby sensors (such as weather stations operated by the National Oceanic and Atmospheric Administration), and remotely sensed data from satellites to measure and analyze environmental conditions, including potential stressors such as weather and land cover and use change.

b) Use measures of environmental variables as covariates in calculating site occupancy, and in basic statistical tests of association, to test whether trends in occupancy are correlated with environmental variables.

Objective 2 Question:
Are any trends in occupancy associated with any trends in environmental variables measured during amphibian monitoring or monitoring other Vital Signs in the GLKN?

Objective 3: Use data on the numbers of animals (i.e., abundance, as opposed to simple presence/absence) of each species observed at each sampling location to complement information on occupancy.

Objective 3 Questions (assessed at only a smaller number of randomly selected intensive-study sites)*:*
Do very few, several (but few enough that individuals may still be identified), or many individuals of each species occupy a site?

Are trends in occupancy associated with trends in the numbers of individuals?

Basic Approach:

At APIS, ISRO, and VOYA, safety concerns dictate that generally only daytime searches be used. For the remaining parks, we are currently weighing relative benefits of performing daytime searches (i.e., visual-encounter surveys) against night-time call surveys that occur along road corridors. Nighttime surveys putatively allow for a greater number of sites to be sampled for a given budget, and would thus provide greater precision on estimates of occupancy for understanding interannual trend. However, restricting surveys to roadsides means taking inference from a population of amphibian sites that likely have very different hydrology, amount of direct human disturbance, and wetland extents compared to all amphibian-inhabited sites within a park. A meeting in February 2007 (mentioned below) will help us weigh the alternatives.

Generally, we will conduct timed daytime visual-encounter surveys (using dipnetting, perimeter searches, and daytime call surveys) and nighttime call surveys, and will bolster daytime sampling of a few sites by using remote recorders at a limited number of sites. We envision using a two-person crew to sample approximately 20 sites per night. Within each park unit, up to thirty sites will be randomly chosen, and will be divided into three subdomains. To establish factors that affect detectability, initial sampling will involve more frequent sampling within a year. Namely, each site will be visited three times during each of three periods in the summer that correspond to the timing of various species' breeding activity periods.

Selection of the desired area of inference is critical to determining the cost of implementing this design, especially if it is applied to all nine parks in the Great Lakes Network in each year. There are 23 amphibian species Network-wide, of which 9 to 19 occur within a given park; we will restrict monitoring to no more than nine to 13 of these 23 species (see "Species to be monitored" below). After pilot work and perhaps $\leq$2 additional years of fieldwork, this suite of species may be reduced even further, due to honing of research questions and budget constraints.

For example, we will evaluate each of the nine parks in terms of the potential area that can be sampled practically within each park. Once we have described areas that can be sampled, we will evaluate those areas in terms of the information available on the locations and types of wetlands. If wetlands can be sufficiently identified such that we can pool wetlands based upon type, we will randomly select a requisite number of sites to sample from such pools. A more likely scenario is that we will not be able to identify wetlands sufficiently to pool them by type. In this case, we will lay geospatial grids over maps of the parks and select cells of habitat to randomly sample. Collaborators have employed this method using 25-ha cells in Voyageurs National Park and St. Croix National Scenic Riverway.

Species to be monitored:

Assemblage 1 (these species breed earlier than species in Assemblage 2 and mostly in temporary wetlands) – wood frog (*Rana sylvatica*), spring peeper (*Pseudacris crucifer*), blue-spotted salamander (*Ambystoma laterale*), spotted salamander (*Ambystoma maculatum*), western and boreal chorus frog (*Pseudacris triseriata triseriata and maculata*);

Assemblage 2 (breed slightly or significantly later, and typically in wetlands with longer hydroperiods, than species in Assemblage 1) – northern leopard frog (*Rana pipiens*), American toad (*Bufo americanus americanus*), eastern gray and Cope's gray treefrog (*Hyla versicolor and chrysoscelis*), mink frog (*Rana septentrionalis*), green frog (*Rana clamitans melanota*), and bullfrog (*Rana catesbeiana*).

Metrics:

The primary metric will be presence of a species at a site, based upon encounter of egg masses, larvae, metamorphs, immatures, or adults; or via standardized call surveys. If none of these evidences are encountered, the species is considered absent (i.e., not detected). Pooling of surveys across an area allows one to estimate site occupancy. We will analyze occupancy data in a manner that accounts for detectability; both analyses will incorporate several covariates, in an information-theoretic analytical framework. The spatial *pattern* of occupancy will also be of interest, because geographical distributions of ectothermic species are predicted to shift northward under regimes of rapid climate change (Schneider and Root (2002).

Covariates:

- pH
- water temperature
- wetland size
- wetland type

- conductivity
- water depth
- air temperature
- relative humidity
- wind speed
- barometric pressure
- various GIS-based data that describe local fragmentation vs. connectivity of the habitat
- presence and type of predators present at breeding sites
- percent emergent vegetation
- percent canopy cover
- type of surrounding habitat
- UTM coordinates
- elevation

Desired limits for detecting change:

We will use occupancy (MacKenzie and Kendall 2002, MacKenzie et al. 2002, Mackenzie et al. 2003) to describe the number of potential sites occupied by individuals of the species being monitored. Based upon currently crude estimates of average occupancies (0.5) and detection probabilities (0.7) as a result of collaborators' work with the above species in Voyageurs National Park and the St. Croix National Scenic Riverway, we will strive to survey ≥30 sites in each park three times during each of three separate sampling periods to achieve a standard error of 0.1 for our estimates of both detectability and occupancy. Sampling intensity within seasons may be relaxed in a subset of years in which we do not assess detectability as rigorously (e.g., 1-2 visits per site per season).

Thresholds or trigger points:

Managers should be concerned when we document:

- Three consecutive years, with conditions suitable for detection, of a species being absent from a site where it previously was known to be present. Concern is greatest for species that have highest site fidelity and the greater the number of site absences (i.e., apparent extirpations) recorded.
- A 35% decline in the occupancy of any species within a park unit.

Principal Investigators and NPS Lead:

The principal investigator is Dr. Walt Sadinski, USGS, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. The NPS lead is Erik Beever, NPS, Great Lakes Inventory and Monitoring Network, Ashland, Wisconsin.

Past work on amphibians in GLKN park units:

While implementation of this protocol will greatly extend our understanding of amphibian dynamics among GLKN parks, the protocol will also benefit from a number of recent, continuing, and planned efforts in the Network. Within the parks themselves, inventories by Gary Casper (Milwaukee Public Museum, Casper Consulting) occurred during 1998-1999 at APIS (Casper 2001), and during 2004-2005 at PIRO (Casper 2005) and ISRO and SLBE (Casper, *in preparation*). Additionally, Walt Sadinski (USGS, La Crosse) has performed surveys in MISS, SACN, and VOYA (Sadinski et al.¸ *in preparation*). Night-time calling surveys during the last four decades have occurred sporadically in all park units of the GLKN (numerous individuals, *unpubl. data*), as have a handful of other surveys (Table 2, Casper 2004). Casper (2004) summarized other past monitoring programs and inventories for amphibians within the Great Lakes Network.

Within the region(al context), the major programs investigating amphibians include the USGS' Amphibian Research and Monitoring Initiative (ARMI), Marsh Monitoring Program (Weeber and Vallianatos 2000), North American Amphibian Monitoring Program (NAAMP; Weir 2005), and other surveys by state natural-resource agencies (e.g., Mossman et al. 1998).

Development Schedule, Budget, and Expected Interim Products:

We will conduct pilot testing during spring and summer, 2006 and 2007, at APIS, SLBE, ISRO, and (to a more limited degree) MISS. Approximately $60,000 has been budgeted to realize this effort in 2006 with a similar amount budgeted for 2007. Through this work, we hope to achieve the following goals:

a) quantify occupancy and a measure of its precision (across surveys) for each monitored amphibian species within each park;
b) compare the cost-effectiveness (and thus possible sampling intensity), logistical efficiency, and detection rates for each species of night-time call surveys vs. daytime searches for target amphibian species;
c) perform direct comparisons of detection rates using the naked ear vs. parabolic recorders;
d) investigate the utility of remotely collected data (e.g., using FrogLogger™ recording devices) to bolster sampling events; and
e) gauge the utility and costs of obtaining estimates or indices of abundance of each species at sites.

In addition to directing and participating in the fieldwork at SLBE and APIS in 2006, the NPS Amphibian Program Manager also visited PIRO, SACN, VOYA, ISRO, GRPO, and (briefly) MISS to better understand the physical, hydrological, and biological foundations that may influence amphibian distributions within each park unit. The NPS lead also worked in concert with skilled field herpetologists to hone field skills and ascertain which species and life-stages are reliably identifiable with a reasonable level of training. Finally, to further inform our approach in the pilot sampling, we envision convening a one- to two-day meeting in February 2007 with individuals who have been instrumental in amphibian work in this region. The NPS lead will have polled the Network's park Ecologists and Chiefs of Natural Resources, to clarify which questions and priorities they hold, with respect to several design trade-offs. The meeting will thus facilitate the decision-making process on these issues, based on data and analyses whenever possible. Following fieldwork in 2006, the NPS lead will summarize the findings from the first year, and make appropriate minor adjustments to the protocol. Following completion of pilot sampling in 2007, a more thorough quantitative assessment of the advantages and disadvantages of the alternatives stated in the goals immediately above will be produced as a report. Refinement of the future sampling schedule may occur after the pilot fieldwork is completed in 2007, and the above five goals are adequately achieved.

Literature Cited:

Casper, G. S. 2001. Amphibian Inventory of the Apostle Island National Lakeshore, with an Evaluation of Malformity Rates, Monitoring Recommendations, and Notes on Reptiles. 25 March Unpublished Report to NPS-APIS.

Casper, G. S. 2004. Amphibian and Reptile Monitoring in the Great Lakes Network National Parks: Review and Recommendations. Great Lakes Inventory and Monitoring Network, Ashland, Wisconsin. Technical Report GLKN/2004/03.

Casper, G. S. 2005. An amphibian and reptile inventory of Pictured Rocks National Lakeshore. Great Lakes Inventory and Monitoring Network, Ashland, Wisconsin. Technical Report GLKN/2005/05

Lannoo . M. (editor) 2005. Amphibian declines: the conservation status of United States species. University of California Press, Berkeley, CA.

MacKenzie D. I., and Kendall W. L. 2002. How should detection probability be incorporated into estimates of relative abundance? Ecology **83**:2387-2393.

Mackenzie D. I., J. D. Nichols, J. E. Hines, M. G. Knutson, and A. B. Franklin. 2003. Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. Ecology **84:**2200-2207.

MacKenzie D. I., J. D. Nichols, G. B. Lachman, S. Droege, J. A. Royle, and C. A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology **83**:2248-2255.

Mossman, M. J., L. M. Hartman, R. Hay, J. R. Sauer, and B. J. Dhuey. 1998. Monitoring long-term trends in Wisconsin frog and toad populations. Pages 169-198 in: M. J. Lannoo, ed., Status and conservation of Midwestern amphibians. Univ. of Iowa Press, Iowa City, IA.

Weeber, R. C., and M. Vallianatos (editors). 2000. The Marsh Monitoring Program 1995-1999: monitoring Great Lakes wetlands and their amphibian and bird inhabitants. Published by Bird Studies Canada in cooperation with Environment Canada and the U.S. Environmental Protection Agency. 47 pp.

Weir, L. 2005. Protocol: Patuxent Wildlife Research Center, North American Amphibian Monitoring Program. (www.pwrc.usgs.gov/NAAMP/protocol). Accessed 15 September 2005.

PROTOCOL DEVELOPMENT SUMMARY – LANDBIRDS

Protocol: Monitoring protocol for landbirds in the Great Lakes I&M Network [short name – landbirds]

Parks Where Protocol will be Implemented: APIS, GRPO, INDU, ISRO, MISS, PIRO, SACN, SLBE, and VOYA

Justification/Issues Being Addressed:

The nine national parks in the Great Lakes Inventory and Monitoring Network (GLKN) provide important breeding and nesting habitat that is protected from extensive human development and subsequent fragmentation. The proximity of all nine parks to a variety of aquatic habitats (e.g., Great Lakes, large rivers, small beaver ponds) and the complexity of terrestrial landscapes (sand dunes, old fields, temperate hardwoods, and southern boreal forest) provide habitat for numerous species of landbirds, many of which are state- and federally-listed as threatened or endangered (e.g., Minnesota DNR 1996, Wisconsin DNR 2004, U.S. Fish and Wildlife Service 2004).

Landbirds play an integral role in park ecosystems. They provide pollination and seed dispersal for native plants and are major links in the food web as both predators and prey (Marquis and Whelan 1994, Holmes 1990). Birds also have high visitor appeal, and as such, enhance visitor enjoyment and awareness of park natural resources (Cordell et al. 1999). Finally, landbirds are relatively high on the food web (Wiens 1989), many are habitat obligates (Cody 1985), the taxonomy is well resolved (Sibley and Monroe 1991), and there are many long-term data sets for regional and national comparisons (Lind et al. 2004, Sauer et al. 2004); hence, they are excellent indicators of ecosystem change. For these reasons the ‘bird community’ Vital Sign was ranked by the Great Lakes Network parks as the fourth highest priority for long-term monitoring (Route 2004).

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

The objective is to conduct monitoring of landbirds each spring as an index of their abundance in parks of the Great Lakes Network, and to use methods that are comparable to other landbird monitoring across the region and the nation. We do not intend to develop a new probabilistic design for landbird monitoring at all parks at this time; rather, for most parks we will adopt transects and points previously established along trails and roads. We will state the assumptions of these designs *a priori*, delineate the limits of the domain in each park, and make qualifications as to how the data can be interpreted. We will also improve upon these efforts by increasing consistency across parks, adding quality control procedures (e.g., training and testing of observers), and managing data (archival, analysis, and reporting). In at least Pictured Rocks National Lakeshore (where no previous monitoring has occurred), and possibly Sleeping Bear Dunes National Lakeshore (where monitoring has been limited), we may develop a probabilistic sampling design. Depending on the results and costs of this approach, we will re-examine how monitoring is conducted in all parks in the future.

Some of the specific monitoring questions that will be addressed by this protocol include:

- What is the species composition and relative abundance of landbirds along transects in parks during the breeding season and are they changing? Knowledge of trends in community composition and species abundance is important to species conservation and for directing future management decisions.
- What are the habitat associations of landbird species? Some bird species are closely associated with specific habitat types during the breeding season and their presence or absence may be helpful in evaluating environmental condition. However this analysis will be dependent on the quality of habitat information that is available.
- How do population trends and habitat associations in the parks compare to those from other monitoring programs in the region? Such comparison is important for understanding the parks' contribution to regional diversity. Several existing monitoring programs (e.g., national forests, USGS Breeding Bird Surveys) can be used for regional comparisons of trends and habitat associations.

Basic Approach:

Six of the nine GLKN parks currently conduct landbird monitoring, while three parks (PIRO, SLBE, and MISS) do not. Each of the existing landbird monitoring programs in the GLKN use point counts to sample landbirds during the breeding season (usually June to early July). Lind et al. (2005) reviewed the existing park protocols and presented a brief description of each park's objectives, cumulative years of data collection, overall sampling design, number of survey points, and data collection procedures. As part of the review, Lind et al. (2005) performed power analyses on the existing data to determine whether trends could be reliably detected over time. They found that most park monitoring programs provide sufficient data to detect significant trends in common species over relatively short (10 to 15 years) timeframes. However, the authors recommended some changes that would enhance the reliability, repeatability, statistical power, and regional consistency of the protocols. In most cases, the existing protocols could be easily revised and new, more rigorous, standards adopted in the field.

Howe et al. (1997) developed a landbird monitoring protocol for the Great Lakes Region. Three of the six parks that currently conduct landbird monitoring would require only minor adjustments to be in full compliance with this protocol (APIS, GRPO, and VOYA). The other three protocols would require some procedural changes including additional data collection. Two GLKN parks currently do not conduct breeding bird monitoring (PIRO and MISS) and one only recently began collecting data (SLBE). We will fully adopt the field methods of Howe et al. (1997) for these three parks and we hope to lay out sampling points using a probabilistic design for two of them (PIRO and SLBE). Sample points at these two parks may be co-located with the vegetation monitoring plots that are being developed by D. Waller and S. Sanders (see protocol development summary for terrestrial vegetation). For logistical reasons, co-location may require sub-sampling a portion of the vegetation plots for landbirds using accessibility as a function for selecting points. Finally, MISS currently does not monitor landbirds, but road- and/or river-based monitoring methods will be considered at this park in conjunction with work being done by Audubon Minnesota.

We will explicitly state the goals and objectives for landbird monitoring at each park and prepare written protocols and SOPs for all nine parks that are as consistent as possible with Howe et al. (1997), as well as NPS protocol standards (Oakley et al. 2003).

The locations of existing sampling points will be documented in GIS themes and we will examine potential biases in the habitats sampled and proximity to natural features and human developments. Recommendations for changes and/or appropriate qualifying statements for future analysis and use of the data will be made in the final protocols. Training and testing for the identification of landbirds and description of habitats will be conducted by the cooperator, with bird species lists from previous park surveys provided by the Network.

Principal Investigators and NPS Lead:

Protocol development is being done through a cooperative agreement with the Natural Resources Research Institute, University of Minnesota Duluth (5013 Miller Trunk Highway, Duluth, Minnesota, 55811, 218-720-4294). The Principal Investigator is Nick Danz and the NPS lead is Bill Route at GLKN.

Development Schedule, Budget, and Expected Interim Products:

The principal investigator will produce a review draft of a template for the protocols by November 2006. After review by the NPS and subsequent revision, interim protocols will be submitted to each park by May 1, 2007. Parks will pilot test these protocols during the breeding bird surveys in June 2007. After incorporation of feedback, the cooperator will submit final protocols by September 2007 for implementation in 2008. We have obligated $22,999 for this protocol development.

We also obligated $8,000 to help the Wisconsin Department of Natural Resources and the University of Wisconsin, Green Bay develop a landbird training and certification web site. The site will cover birds of the western Great Lakes and will document both auditory and visual abilities of observers. Observers will need to pass the exam with a score of >80% to be an observer for the NPS landbird protocol. This site is slated for being functional prior to the 2007 breeding bird monitoring season.

Literature Cited:

Cody, M. L., editor. 1985. Habitat selection in birds. Academic Press, San Diego, California.

Cordell, H. K., N. G. Herbert, and F. Pandolfi. 1999. The growing popularity of birding in the United States. Birding **31**:168–176.

Holmes, R. T. 1990. Ecological and evolutionary impacts of bird predation on forest insects: An overview. Studies in Avian Biology **13**:6-13.

Howe, R. W., G. J. Niemi, G. J. Lewis, and D. A. Welsh. 1997. A standard method for monitoring songbird populations in the Great Lakes region. Passenger Pigeon **59**:182-194.

Lind, J., N. Danz, and J. M. Hanowski. 2005. Analysis of landbird monitoring data for national parks in the Great Lakes Network. Great Lakes Inventory and Monitoring Network Report GLKN/2005/08.

Lind, J., N. Danz, J. M. Hanowski, and G. J. Niemi. 2004. Breeding bird monitoring in Great Lakes National Forests: 1991-2004. Natural Resources Research Institute Technical Report: NRRI/TR-2005/04. www.nrri.umn.edu/mnbirds/reports.htm.

Marquis, R. J., and C. J. Whelan. 1994. Insectivorous birds increase growth of white oak through consumption of leaf-chewing insects. Ecology **75**:2007-2014.

Minnesota Department of Natural Resources. 1996. Minnesota's list of endangered, threatened, and special concern species. Natural Heritage and Nongame Research Program. www.dnr.state.mn.us/ets/index.html (accessed on 13 October 2005).

Oakley, K. L., L. P. Thomas, and S. G. Fancy. 2003. Guidelines for long-term monitoring protocols. Wildlife Society Bulletin **31**:100-103.

Route, B. 2004. Process and results of selecting and prioritizing Vital Signs for the Great Lakes Network. U.S. National Park Service, Great Lakes Inventory and Monitoring Network. Technical Report GLKN/2004/05.

Sauer, J. R., J. E. Hines, and J. Fallon. 2004. The North American Breeding Bird Survey, results and analysis 1966 - 2003. Version 2004.1, USGS Patuxent Wildlife Research Center, Laurel, Maryland. www.mbr-pwrc.usgs.gov/bbs/bbs.html,

Sibley, C. G., and B. L. Monroe. 1991. Distribution and taxonomy of the birds of the world. New Haven, USA: Yale University Press, New Haven, Connecticut.

U.S. Fish and Wildlife Service. 2004. Endangered, threatened, proposed, and candidate species in Region 3 of the U.S. Fish and Wildlife Service. www.fws.gov/midwest/Endangered/LISTS/e_th_pr.html (accessed on 13 October 2005).

Wiens, J. A. 1989. The ecology of bird communities, volume 1: Foundations and patterns. Cambridge University Press, Cambridge, Massachusetts.

Wisconsin Department of Natural Resources. 2004. Wisconsin state threatened and endangered species. Wisconsin DNR Endangered Resources Program. PUBL-ER-001 2004. www.dnr.state.wi.us/org/land/er/ (accessed on 13 October 2005).

Protocol Development Summary – Terrestrial Vegetation

Protocol: General terrestrial vegetation monitoring protocol for the Great Lakes Network [short name: terrestrial vegetation]

Parks Where Protocol Will be Implemented: APIS, GRPO, INDU, ISRO, MISS, PIRO, SACN, SLBE, VOYA

Justification/Issues Being Addressed:

Terrestrial vegetation was ranked third among the 46 Vital Signs evaluated by the Great Lakes Network for incorporation into a long-term monitoring strategy. Terrestrial vegetation serves as an integrated measure of terrestrial ecosystem health by expressing information about climate, soils, and disturbance (Randerson et al. 2002). Further, terrestrial vegetation serves as a trophic base for other ecosystem components (Fortin et al. 2005). Because of this interwoven relationship between terrestrial vegetation and both biotic and abiotic forest components, we will develop a comprehensive protocol that incorporates the Network's monitoring plans for terrestrial vegetation as well as those of related Vital Signs, including terrestrial pests and pathogens, problem species, succession, and soils.

Current stressors (threats) to vegetation in NPS units

Many Great Lakes Network parks have experienced the invasion of recently introduced forest pathogens. The beech scale insect (*Cryptococcus fagisuga*, causal agent of beech bark disease) is now present on beech (*Fagus grandifolia*) trees in Pictured Rocks National Lakeshore and is present in the counties immediately adjacent to Sleeping Bear Dunes National Lakeshore. Emerald ash borer has been confirmed in the county adjacent to Indiana Dunes National Lakeshore and in the Upper Peninsula of Michigan and is spreading northward and westward. Exotic European earthworms have been reported in multiple Great Lakes Network parks and are rapidly changing soil properties (Gundale 2005), which in turn influence the herbaceous plant community (Hale 2004). Other introduced pathogens (e.g., hemlock wooly adelgid, Asian long-horned beetle), while not yet present at GLKN parks, pose a high risk for invasion and consequent adverse impacts on forest health.

In addition to exotic species, changes in management and land use have led to uncharacteristic expansion of a few native taxa, such that they have become problem species. The most notable example of this is the irruption of the native white-tailed deer (*Odocoileus virginianus*) population. Browse pressure by deer has reduced the abundance of certain native plant species (e.g., Canada yew (*Taxus canadensis*), eastern hemlock (*Tsuga canadensis*)) to a fraction of their previous abundance (Russell 2001). Further, overbrowsing by deer is driving change at the community level by promoting the biotic homogenization of Great Lakes forests (Rooney et al. 2004). For these reasons, white-tailed deer is the major problem vertebrate threatening the health of Great Lakes forests.

Predicted uses of terrestrial-vegetation monitoring

Routine monitoring of forest health will: provide an understanding of natural variability of vegetation in 'benchmark' areas that are comparatively undisturbed, provide an early warning of undesirable trends in vegetation, allow adaptive management of forest ecosystems, and allow for inferences on overall forest health.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Terrestrial vegetation

1) Are plant communities changing? We will measure species richness and community composition and test for change in these variables. We will also test for shifts in relative abundance and dominance of species as well as determine whether community homogenization is occurring.

2) Is plant community structure changing? We will measure canopy cover, shrub density and cover, basal area distribution of trees, herb density, herb cover, and downed woody debris. Structural changes will provide insight into successional and regenerative processes in the parks, and can be assessed as to how these may be affected by other drivers of change such as deer and pests and pathogens.

Terrestrial pests and pathogens

Which key terrestrial pests and pathogens are present in Great Lakes national parks and at what abundance? We are developing a list of target pests and pathogens (both native and exotic) for which to search. We will explore methods for their quantification. We will then use logistic regression to relate presence/absence of the pathogens, and linear regression to relate abundance, to changes in plant species, communities, and community structure.

Problem species

To what degree is deer browse evident on terrestrial vegetation? We will measure percent browse on key plant species within the vegetation plots and relate this to changes in plant species, communities, and community structure.

Succession

Are Great Lakes Network forests exhibiting expected successional trajectories? We will use information on plant community change and place this into context with what is known about successional trajectories. Community change will then allow us to make inferences about the successional state of forests of Great Lakes national parks.

Soils

Are the depths of soil horizons changing at sites, between sampling events? Because earthworms can change soil horizon depth and cause consequent changes in herbaceous plant diversity, we will test for associations between earthworm presence and abundance with herbaceous plant density, cover, and species composition.

Basic Approach:

We will be using a probabilistic sampling design, whereby sample sites will be selected from a random grid using the generalized random-tessellation stratified (GRTS) method (Stevens and Olsen 2004). If we are unable to select sample sites from the entire area of each park, we will limit our sampling domain (likely by criteria associated with accessibility and safety of field crews) *a priori*. The sampling plot type will be selected during winter 2005-2006 based on field work conducted during summer 2005 (see expected interim products, below). Vector change analysis (Fulton and Harcombe 2002) will be used to test for changes in community structure.

Principal Investigators and NPS Lead: The principal investigator is Dr. Don Waller who, along with Sarah Johnson (both of the University of Wisconsin – Madison) will co-write the protocol with NPS lead, Suzanne Sanders.

Development Schedule, Budget, and Expected Interim Products:

One Project, which will facilitate completion of this protocol, is nearly finalized. This project is a comparison of three vegetation plot types, and is being undertaken by Dr. Don Waller. For this project, U.S. Forest Service Forest Inventory and Analysis (FIA) sampling methods were directly compared with Plant Ecology Laboratory (PEL) methods developed by Curtis (1959). Field work was carried out during summer 2005 at APIS, with the initial intent of conducting a comparison of the same two sampling designs at PIRO. However, a third vegetation sampling type was developed that was a hybrid of the two methods, encompassing the benefits of both. This hybrid plot was designed to be sampled more quickly than the PEL plot, and to provide more information than the FIA plot. At PIRO, FIA plots were directly compared with the hybrid plots. The draft report for this project was submitted August 8, 2006 and is currently in revision.

The protocol is nearly complete, with final details now being added. We have contacted two peer reviewers and will submit the protocol for review October 16, 2006. We intend to implement the terrestrial vegetation protocol during the field season of 2007. Tentatively, we have budgeted $35,000 annually for field work, although this figure is expected to change as methods are refined.

Literature Cited:

Curtis, J. T. 1959. The vegetation of Wisconsin: An ordination of plant communities. The University of Wisconsin Press, Madison, Wisconsin.

Fortin, D., H. L. Beyer, M. S. Boyce, D. W. Smith, T. Duchesne, and J. S. Mao. 2005. Wolves influence elk movements: behavior shapes a trophic cascade in Yellowstone National Park. Ecology **86**:1320–1330.

Fulton, M., and P. A. Harcombe. 2002. Fine-scale predictability of forest community dynamics. Ecology **83**:1204-1208.

Gundale, M. J., W. M. Jolly, and T. H. Deluca. 2005. Susceptibility of a northern hardwood forest to exotic earthworm invasion. Conservation Biology **19**:1075-1083.

Hale, C. 2004. Ecological consequences of exotic invaders: interaction involving European earthworms and native plant communities in hardwood forests. Ph.D. dissertation. University of Minnesota, St. Paul, Minnesota.

Randerson, J. T., F. S. Chapin, J. W. Harden, J. C. Neff, and M. E. Harmon. 2002. Net ecosystem production: a comprehensive measure of net carbon accumulation by ecosystems. Ecological Applications **12**:937–947.

Rooney, T. P., S. M. Weigmann, D. A. Rogers, and D. M. Waller. 2004. Biotic impoverishment and homogenization in unfragmented forest understory communities. Conservation Biology **18**:787-798.

Russell, F. L., D. B. Zippin, and N. L. Fowler. 2001. Effects of white-tailed deer (*Odocoileus virginianus*) on plants, plant populations and communities: A review. American Midland Naturalist **146**:1-26.

Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association **99**:262-278.

PROTOCOL DEVELOPMENT SUMMARY – LAND COVER/LAND USE: COARSE SCALE

Protocol: Long-term monitoring of land cover and land use in the Great Lakes Network – Coarse Scale (short name: LCLU Coarse Scale)

Parks Where Protocol will be Implemented: APIS, GRPO, INDU, ISRO, MISS, PIRO, SACN, SLBE, VOYA

Justification/Issues Being Addressed:

The Great Lakes Network is developing two land cover/land use (LCLU) protocols (coarse scale and fine scale) as part of the overall Vital Signs monitoring program. Landscape scale properties such as terrain, hydrology, soils, geology, and climate provide the foundation on which other resources exist and function. This protocol development summary addresses coarse scale LCLU, which was ranked as the fifth highest priority Vital Sign.

The fine and coarse scale approaches differ in the spatial grain (i.e., resolution) of remote sensors, in the extent of the area of interest, and in the level of accuracy and detail in data. Whereas some Vital Signs monitoring questions require information from a broad, landscape context, such as those dealing with watershed relationships, (rainfall runoff rate and volume, or fragmentation), other questions involve a much smaller extent, such as defining changes in road and building density adjacent to parks, small scale patch dynamics (wetlands, open areas), and bluff and dune changes along shorelines.

The two LCLU protocols share questions, justifications, and metrics, but the tools, techniques, and accuracies of both are quite different. The Network is currently researching numerous technologies and techniques to assess land cover at coarse and fine scales. It is unlikely that methods for one scale alone will adequately address all of the landscape scale questions. However, funding will limit the amount and type of data that can be collected.

Specific Monitoring Questions to be Addressed by the Protocol:

- What is the magnitude and direction of change in spatial patterns of LCLU in and adjacent to, parks over time? Spatial patterns include such measures as land cover class, corridors, fragmentation, juxtaposition, edge, number of homes, etc.
- What are the changes in area and shape in urban, agricultural, and other areas dominated by human land use within a defined monitoring region for each park?
- What are the changes in forest harvest amounts and patterns within and surrounding each park in specified areas?
- How has the density of human occupation, measured either by population or building density, changed in each monitoring region?

Basic Approach:

Multi-temporal, classified, mid-resolution satellite imagery such as the National Land Cover Dataset (NLCD) can provide metrics that reveal changes in runoff rate and volume, stream flow dynamics, succession and human development. The Network will incorporate these coarse-scale data into the landscape monitoring as data from other state, federal, or partner efforts are completed. These data will provide valuable information for the larger, watershed extent as it is pertinent to each park.

Three additional data sets will contribute to the coarse scale LCLU program:

1. The most recent population density data will be collected for the study region, corresponding to the most recent decadal census or approximate five year updates.
2. Moderate resolution elevation data (10 – 30 m postings) will be obtained for each study area prior to classification.
3. Wetlands base data will be developed for the study region and verified for accuracy. These data will identify the wetland/upland boundaries, but not the vegetation types or LCLU classes within the wetlands or upland classes.

Metrics will include both measured and derived variables. Land cover classes will be measured based on park area, and contributing area, and population density and housing density will be obtained as complementary data. Metrics derived from the land cover classes will include size, shape, forest edge density, distance to agriculture/urban edge, and measures of contagion and fragmentation.

Principal Investigators and NPS Lead:

The principal investigator is Dr. Paul Bolstad, Forest Resources Department, University of Minnesota. The NPS lead is Ulf Gafvert, GIS Specialist with the Great Lakes Inventory and Monitoring Network.

Development Schedule, Budget, and Expected Interim Products:

The principal investigator is currently developing guidelines and specifying the metrics and accuracies that can be derived using imagery with varying spatial grain, spectral ranges, seasonality, and temporal series. Full protocol implementation will occur in 2007. The Network has obligated $20,000 for the collective development of both coarse scale and fine scale land cover/land use protocols and expects to budget approximately $100,000 for initial implementation of both in 2007.

PROTOCOL DEVELOPMENT SUMMARY – LAND COVER/LAND USE: FINE SCALE

Protocol: Long-term monitoring of land cover and land use in the Great Lakes Network – fine scale (short name: LCLU fine scale)

Parks Where Protocol will be Implemented: APIS, GRPO, INDU, ISRO, MISS, PIRO, SACN, SLBE, VOYA

Justification/Issues Being Addressed:

Two Vital Signs related to land cover/land use were scored by Network parks. The first, coarse scale LCLU, is described in a separate protocol development summary. The second, fine scale LCLU, is the topic of this summary. Although the two approaches share many common ecological questions and similar metrics, they differ in spatial grain, extent of area of interest, and accuracy. Fine scale land cover and land use change was ranked as the twelfth highest priority Vital Sign. Land cover and land use largely set the framework within which other resources exist and function. Habitat quality, species population health and viability, water and land resources, recreational and scenic value, and many other important park attributes depend upon appropriate land cover. Monitoring changes in land cover and land use is important for gauging the context in which other Vital Signs exist and change.

Specific Monitoring Questions to be Addressed by the Protocol:

- What is the magnitude and direction of change in spatial patterns of LCLU in and adjacent to parks over time? Spatial patterns include such measures as land cover class, corridors, fragmentation, juxtaposition, edge, number of homes, etc.
- What are the changes in area and shape in urban, agricultural, and other areas dominated by human land use within a defined monitoring region for each park?
- What are the changes in forest harvest amounts and patterns in each park monitoring region?
- How has the human occupation density, measured either by population or building density, changed in each monitoring region?

Basic Approach:

We will have two sampling extents for use with the primary land cover/land use metrics. A small-area extent is defined by the park boundary plus a 400 m buffer (hereafter called ‘park area’). The second, broader, sampling extent will be based on a modified hydrologic unit code (HUC) boundary, hereafter called ‘contributing landscape’. The extent will be defined by the 10-digit HUC, except in instances where this is truncated or expanded because of local conditions. These extents will be fixed before the initial sampling, and will serve as templates for all subsequent sampling.

The park area defined by a 400 meter buffer is based in part on budget constraints, yet is significant in monitoring effects of immediately adjacent land use change, fragmentation, wildlife corridors, vectors for exotic invasion, and impact of cats/dogs to within park area species.

The HUC boundary is a relevant extent in addressing coarse scale landscape metrics as this is the extent wherein water relations such as rainfall runoff, nutrient and energy transfer through the system, (from upper to lower positions in the watershed), and sedimentation/erosion issues can directly affect park natural resources.

We will develop a suite of metrics to quantify the park areas and contributing landscapes. These metrics will allow us to derive or develop the following:

1. Detailed land cover/land use maps, including vegetation map categories at the National Vegetation Classification System (NVCS) formation level;
2. Inventory of built structures, including
   a) roads and other structures to support motorized vehicles (e.g., parking lots, driveways, and other paved surfaces);
   b) buildings and associated sidewalks, patios, and pedestrian areas;
   c) other human-made structures and corridors, including powerlines, pipelines, dams, bridges;
3. Location and condition of trails;
4. Campsite locations and conditions;
5. Coastline/bluff edge, sand bar, beach, and spit locations;
6. Stream location/bank.

Methods for developing maps and identifying structures (points 1 and 2 above) are based on vegetation and infrastructure inventory and mapping guidelines reported in the literature (Lillesand et al. 2004, Davis and Wang 2003, Goetz et al. 2003, Paine and Kiser 2003, Alpin et al. 1999, Tiner 1999, NPS 1994, Kuchler 1988). Field sampling associated with this protocol will likely be coordinated with the protocols for both vegetation and water quality monitoring for large rivers.

We will have a five to seven year revisit cycle for metrics related to fine scale LCLU monitoring. Mapping and identification of structures will be accomplished using data from field visits and fine resolution satellite or aerial image interpretation.

Metrics will include those described earlier (LCLU coarse scale PDS) as well as additional variables quantifying both human-made structures and natural features. Human-made structures will include attributes of roads (e.g., location, type, density) and trails and campsites (e.g., the proportion of degraded or impacted trail segments, average area of campsite impact, and frequency and size of severe impact). Metrics of natural features will include wetland area; sand spit location, size, and shape; and large changes (> 3 m perpendicular shift) in stream channel location.

Principal Investigators and NPS Lead:

The principal investigator is Dr. Paul Bolstad, Forest Resources Department, University of Minnesota. The NPS lead is Ulf Gafvert, GIS Specialist with the Great Lakes Inventory and Monitoring Network.

Development Schedule, Budget, and Expected Interim Products:

Protocol development will be ongoing in 2006 with implementation occurring in 2007. The Network has obligated $20,000 for the collective development of both coarse scale and fine scale land cover/land use protocols and expects to budget approximately $100,000 for initial implementation.

Literature Cited:

Alpin, P., P. M. Atkinson, and P. J. Curran. 1999. Fine spatial resolution simulated satellite sensor imagery for land cover mapping in the United Kingdom. Remote Sensing of Environment **68**:206-216.

Davis, C. H., X. Wang. 2003. Planimetric accuracy of Ikonos 1 m panchromatic orthoimage products and their utility for local government GIS basemap applications. International Journal of Remote Sensing **24**:4267-4288.

Goetz, S. J., R. K. Wright, A. J. Smith, E. Zinecker, and E. Schaub. 2003. IKONOS imagery for resource management: Tree cover, impervious surfaces, and riparian buffer analyses in the mid-Atlantic region. Remote Sensing of Environment **88**:195-208

Kuchler, A. W. 1988. Vegetation mapping. Kluwer Academic Publishers, Boston, Massachusetts.

Lillesand, T. M., R. W. Kiefer, and J. Chipman. 2004. Remote sensing and image interpretation, 5th edition, Wiley, New York.

NPS (National Park Service). 1994. Vegetation Mapping Program final draft for field methods.

Paine, D., and J. Kiser. 2003. Aerial photography and image interpretation, 2nd edition, Wiley, New York.

Tiner, R. W. 1999. Wetland indicators: A guide to wetland identification, delineation, classification, and mapping, Lewis Publishers, Boca Raton, Florida.

PROTOCOL DEVELOPMENT SUMMARY – DIATOMS

Protocol: Monitoring water quality using diatoms in surficial lake sediments. [short name: diatoms]

Parks Where Protocol will be Implemented: ISRO, VOYA, PIRO, SLBE, INDU, APIS, SACN, MISS

Justification/Issues Being Addressed:

The goal of this project is to develop a protocol for monitoring water quality in lakes that will contribute to an understanding of water quality changes in parks of the Great Lakes Network (GLKN). In GLKN parks, climate change, environmental contaminants, exotic species, and land and resource uses including shoreline and urban development, recreation, water level management, logging, and agriculture have raised concerns about the state of the parks' resources and how best to mange them in a future certain to bring change.

Diatoms are among the most powerful groups of biological indicators of environmental conditions in aquatic systems (lakes, rivers, wetlands, estuaries; Batterbee et al. 2001). Analysis of diatoms in surficial lake sediments can be an important tool to detect recent environmental change, or to place modern conditions in a regional or historical context.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

The analysis of diatoms in surficial lake sediments will address the following questions:

- What is the current ecosystem status of a particular lake in relation to other lakes in the region?
- Are similar ecological trends occurring across lakes in the region?
- What is the ecosystem status of this lake in relation to historical environmental change noted in regional sediment cores?
- When did exotic species X appear in the lake? (Some diatoms are exotic species and can act as negative bellwether taxa; other exotics (e.g., spiny waterflea, *Bythotrephes cederstroemi*) can also be monitored via analysis of surficial sediments.)

To answer these questions the following steps will be taken:

1. Analyze diatom communities in surficial lake sediments to complement the routine physical and chemical water quality sampling and enhance the potential of detecting long-term changes in water quality.

a) The sensitivity and tolerance of diatoms to environmental variables – including nutrients, organic pollutants, pesticides, heavy metals, salinity (and major ion chemistry), pH, alkalinity, light, temperature, substrate, and depth – are known to vary among species (Battarbee et al. 2001). These species-specific responses can be used to infer environmental conditions and to provide an early-warning on the cumulative impacts of environmental change at the base of aquatic foodwebs.

b) Diatoms occur in highly diverse assemblages, and species are relatively easily distinguished. The taxonomic diversity of diatom communities provides a high level of redundancy (confirmation by responses from multiple species) for robust tracking of environmental conditions.

c) The combined cost of diatom sampling and analysis is relatively low when compared to other biological indicators (Stevenson and Pan 1999). Also, diatom samples are easily archived and preserved semi-indefinitely, allowing samples to be re-examined at future dates, if desirable.

d) In lake environments, the deep-water sediments provide a highly integrated sample of diatom community structure for the lake as a whole, which means that only a single sample of surface sediment is needed to characterize the entire lake (Anderson 1990) as compared to the numerous samples required to overcome spatial heterogeneity for other bioindicators (e.g., benthic invertebrates).

e) Diatoms have been used extensively to assess environmental conditions in freshwaters. Literally dozens of papers are published each year in peer-reviewed journals describing analytical and numerical (statistical) methods, taxonomic refinements, environmental requirements, paleo-environmental constructions, and applications in water-quality issues and policy development (Stoermer and Smol 1999). Diatoms are currently being used in state (e.g., Minnesota, Montana) and nation-wide (EMAP, NAWQA) assessments of water quality.

2. Analyze changes in the community composition of diatoms within the context of the range of natural variability, as determined by diatoms present in cores dating back to the time of European settlement.

The question of natural variability is particularly important to environmental monitoring, which in the final analysis aims to distinguish significant human perturbations from background conditions. Because of the often high natural variability of ecological systems (seasonally and interannually), it can take decades of careful water monitoring to detect any significant trends. Even where long-term data sets are available, it is often difficult to know whether the observed trends are of concern or within the range of natural variation. Comparing the current community composition of diatoms to the species compositions dating back 150-200 years will allow us to determine if the current conditions are outside of the range of natural variability of GLKN park lakes.

3. Compare with water chemistry measurements to derive understanding of diatom response to physical/chemical variables.

Because diatom assemblages are highly diverse, they are readily compared using multivariate techniques such as ordination. Differences among samples (in space or time) are summarized by dissimilarity metrics such as chord distance or by arraying them along one or a few major axes in multivariate space (principal component analysis or similar techniques). If independent water quality measurements have been taken (e.g., pH, total phosphorus, temperature), the ordination can be constrained so that the major axes of diatom variability are aligned with the most explanatory environmental gradients (correspondence analysis); the strength of these relationships can then be summarized statistically as an objective measure of explained variance (Battarbee et al. 2001).

Basic Approach:

Develop sampling protocol:

A detailed methodology for sampling will be developed to complement the physical and chemical water quality monitoring protocol currently under development. The sampling strategy will be patterned in part after the project design of the federal NAWQA and EMAP monitoring programs (Hunsaker and Carpenter 1990, http://water.usgs.gov/nawqa/). Both of these programs have adopted a rotating sampling scheme where a set of lakes or rivers is sampled for several years, and sampling then moves to other sets of watersheds, until the rotation returns to the original set of lakes and rivers that were sampled. In our case, lakes will be sampled every year, and rivers every other year, for routine physical and chemical variables, with diatoms being sampled on a rotation of approximately five years.

Develop protocols for diatom sample and slide preparation and for analysis of diatoms on slides:

Methodology will follow standard protocols already in practice at the St. Croix Watershed Research Station. In addition, we will consult protocols for diatom sample preparation and analysis that have been established by the federal NAWQA monitoring program.

Principal Investigators and NPS Lead:

The principal investigators are Dr. Daniel Engstrom, Dr. Mark Edlund, and Joy Ramstack (St. Croix Watershed Research Station), and Dr. Brenda Moraska Lafrancois (National Park Service). The NPS lead is Joan Elias (715-682-0631 ext. 24; Joan_Elias@nps.gov).

Development Schedule, Budget, and Expected Interim Products:

The principal investigators will prepare a draft of the protocol by December, 2006. The Network has budgeted $20,000 for the development of this protocol.

The schedule for monitoring diatoms in surficial sediments will correspond to those for monitoring water quality in inland lakes and large rivers. These two protocols are currently under development through partnerships with the University of Minnesota-Duluth, Natural Resources Research Institute (inland lakes) and the St. Croix Watershed Research Station (large rivers), and are expected to be finalized during fiscal year 2007.

In a related project funded by GLKN, collaborators at the St. Croix Watershed Research Station are analyzing diatoms from lake sediment cores to determine variability in water quality parameters over the past 150-200 years. Results from Pictured Rocks National Lakeshore and Sleeping Bear Dunes National Lakeshore will be complete in spring 2006. During 2006, lakes at two or three additional GLKN parks will be cored for analysis of the variability in historical water quality conditions.

Literature Cited:

Anderson, N. J. 1990. Variability of diatom concentrations and accumulation rates in sediments of a small lake basin. Limnology and Oceanography **35**:497-508.

Battarbee, R. W., V. J. Jones, R. J. Flower, N. G. Cameron, H. Bennion, L. Carvalho, and S. Juggins. 2001. Diatoms. Pages 155-202 *in* J. P. Smol, H. J. B. Birks, and W. M. Last, editors. Tracking environmental change using lake sediments. Volume 3: Terrestrial, algal, and siliceous indicators. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Hunsaker, C. T., and D. E. Carpenter, editors. 1990. Environmental monitoring and assessment program: Ecological indicators. EPA-600-3-90-060. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

Stevenson, R. J., and Y. Pan. 1999. Assessing environmental conditions in rivers and streams with diatoms. Pages 11-40 *in* E. F. Stoermer, and J. P. Smol, editors. The diatoms: Applications for the environmental and earth sciences. Cambridge University Press, Cambridge & New York.

Stoermer, E. F., and J. P. Smol, editors. 1999. The diatoms: Applications for the environmental and earth sciences. Cambridge University Press, Cambridge & New York.

PROTOCOL DEVELOPMENT SUMMARY – WADEABLE STREAMS

Protocol: Monitoring water quality in wadeable streams of national park units of the Great Lakes Inventory and Monitoring Network [short name: wadeable streams]

Parks Where Protocol will be Implemented: GRPO, INDU, PIRO, SLBE.

Justification/Issues Being Addressed:

Water quality is among the highest ranked Vital Signs for monitoring by the Network (Route 2004). The Network, in collaboration with partner organizations, is nearing completion of the development of protocols for monitoring basic water quality parameters of inland lakes and large rivers. These protocols, which are limited to basic chemical and physical parameters (e.g., nutrients, pH, dissolved oxygen, major ions, Secchi depth), do not include biotic measures, other than chlorophyll *a*, and do not encompass the smaller, wadeable streams. Some parks within GLKN contain few or no inland lakes or large rivers, and yet have important aquatic resources in the form of wadeable streams (e.g., GRPO, INDU).

The wadeable streams in GLKN parks have experienced varying degrees of impacts from human activities, and face an uncertain future in which water quality may be threatened by climate change, development, land use practices, and recreation. Documented impacts or threats include nutrient loading in the Platte River and dam-regulated low flow in the Crystal River, both in SLBE (Vana-Miller 2002); invasion by the exotic sea lamprey (*Petromyzon marinus*) in Miner's Creek, PIRO (L. Loope, NPS PIRO, personal communication) and several streams in SLBE (S. Yancho, NPS SLBE, personal communication); fish consumption advisories and other evidence of degradation in the Grand Calumet River, INDU (Ledder 2003).

The objective of this project is to develop a protocol for monitoring water quality in wadeable streams that will be consistent with and complement the protocols for inland lakes and large rivers. In contrast to large river systems, the wadeable streams tend to have more dynamic streamflow and more variable water chemistry. Adequately tracking water quality trends in smaller streams may require monitoring water quality parameters that integrate the effects of several physical and chemical parameters. Therefore, incorporating biotic indicators, such as macroinvertebrates, into the wadeable streams protocol may be desirable.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

The overall monitoring objective is to determine trends in water quality of wadeable streams in GLKN park units, using methods that are comparable to state and other monitoring efforts currently underway.

Some of the specific monitoring questions this protocol will be designed to answer include:

- What are the status and trend (rate and direction of change) in systematic flow regime in select streams?

- What are the status and trend (rate and direction of change) in select water quality parameters, including temperature, pH, specific conductance, dissolved oxygen, water clarity, and sediment loads in select streams?
- What are the trends in the species composition and abundance of select biotic indicator taxa?

We will continue to refine and add to these monitoring questions as we develop the protocol.

Basic Approach:

The approach taken in the GLKN parks will be consistent with the large rivers protocol (Magdalene et al., in prep.), the USGS stream sampling protocol (Gilliom et al. 1995), and the EPA Wadeable Streams Assessment (McDonald et al. 2002). Samples will be collected according to standard methodologies, along with quality assurance and quality control measures, such that all data are representative of the measured parameters with respect to time, location, and conditions.

Water Quality Parameters: To be consistent with the large rivers protocol, parameters such as flow, temperature, specific conductance, pH, dissolved oxygen, clarity, alkalinity, total suspended solids, total phosphorus, total nitrogen, nitrite + nitrate-nitrogen, and major ions will be considered. The desired sampling frequency of these parameters will be determined from analysis of available historical data, but budget considerations must also play a role. Existing macroinvertebrate indices will be researched and evaluated for ease of use and applicable inference to water quality conditions. It is likely that the biotic indicator(s) chosen will be one (or more) that does not require a great deal of taxonomic expertise, such as the Hilsenhoff index (1988), which is based on family-level identification. Additional observations may include photo-documentation and visual assessment of streambed, streambanks, and vegetation surrounding the stream, similar to the EPA Wadeable Streams Assessment methods (USEPA 2004).

Survey Design: In GLKN parks centered on large rivers (the St. Croix and Namekagon Rivers within SACN, and Mississippi River within MISS), only the mainstems of the rivers are contained within park boundaries. In contrast, some of the other parks within GLKN contain large portions of wadeable streams and their contributing watersheds. Therefore, the survey design of the wadeable streams monitoring protocol will likely differ from that of large rivers. Most likely, a combination of randomly selected sites and nonrandom, targeted sites will be included in this protocol.

Principal Investigators and NPS Lead:

The protocol is being developed through a cooperative task agreement with the St. Croix Watershed Research Station (SCWRS), 16910 152nd St. N., Marine on St. Croix, MN 55047, (651) 433-5953. Principal investigators Suzanne Magdalene and Daniel Engstrom (both of SCWRS) are working with Joan Elias (GLKN), Ashland, Wisconsin, 715-682-0631, to develop the protocol.

Development Schedule, Budget, and Expected Interim Products:

A draft of the protocol will be submitted for NPS and peer review will occur in spring or summer 2007. Review comments will be addressed and the final protocol will be completed by December 30, 2007. The Network has budgeted $20,056 for development of this protocol.

In a project related to both this protocol for wadeable streams and the protocol for monitoring water quality in large rivers (currently nearing completion), the Network has an agreement with SCWRS to establish sampling sites on the St. Croix and Namekagon Rivers. As part of this project, SCWRS staff will train the GLKN aquatic ecologist in site establishment techniques, including the determination of discharge rating curves. The methods for establishing sites on these large rivers will be transferable to wadeable streams.

Additional related projects include the development of monitoring protocols for inland lakes, in collaboration with the University of Minnesota-Duluth, Natural Resources Research Institute, and large rivers, in collaboration with the St. Croix Watershed Research Station. We expect these protocols to be complete in the winter/spring of 2006.

Literature Cited:

Gilliom, R. J., W. M. Alley, and M. E. Gurtz. 1995. Design of the national water-quality assessment program: Occurrence and distribution of water-quality conditions. United States Geological Survey Circular 1112.

Hilsenhoff, W. 1988. Rapid field assessment of organic pollution with a family-level index. Journal of North American Benthological Society **7**:65-68.

Ledder, T. 2003. Water resource information and assessment report for the Great Lakes Inventory and Monitoring Network. National Park Service, Great Lakes Inventory and Monitoring Network, Ashland, Wisconsin. 54806. Great Lakes Technical Report: GLKN/2003/05.

Magdalene, S., D. Engstrom, and J. Elias. In preparation. Water quality monitoring protocol for large rivers. Version 1.0. National Park Service, Great Lakes Inventory and Monitoring Network Report GLKN/2005/13.

McDonald, M. E., S. Paulsen, R. Blair, J. Dlugosz, S. Hale, S. Hedtke, D. Heggem, L. Jackson, K. B. Jones, B. Levinson, A. Olsen., J. Stoddard, K. Summers, and G. Veith. 2002. Research strategy of the Environmental Monitoring and Assessment Program. EPA 620/R-02/002.

Route, B. 2004. Process and results of selecting and prioritizing Vital Signs for the Great Lakes Network. U.S. National Park Service, Great Lakes Inventory and Monitoring Network. Technical Report GLKN/2004/05.

USEPA. 2004. Wadeable stream assessment: Field operations manual. EPA841-B-04-004. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, D.C.

Vana-Miller, D. 2002. Water resources management plan for Sleeping Bear Dunes National Lakeshore. National Park Service, Water Resources Division, Fort Collins, Colorado.

PROTOCOL DEVELOPMENT SUMMARY – CLIMATE

Protocol: Monitoring protocol for weather and climate change in the Great Lakes Network parks [short name: climate]

Parks Where Protocol will be Implemented: APIS, GRPO, INDU, ISRO, MISS, PIRO, SACN, SLBE, and VOYA

Justification/Issues Being Addressed:

Climate was ranked as the eleventh highest priority Vital Sign in the Great Lakes Network. Climate is a primary driver of almost all physical and ecological processes in the Great Lakes Network (GLKN). Climate controls ecosystem fluxes of energy and matter as well as the geomorphic and biogeochemical processes underlying the distribution and structure of these ecosystems (Bonan 2002). The effects of climate are especially visible in areas near large waterbodies, such as the Great Lakes (Moran and Hopkins 2002). Conceptual ecosystem models for the GLKN have also emphasized the influence of climate on other Vital Signs in the region (Gucciardo et al. 2004).

Evidence from ecological indicators of climate, such as glacial ice, lake sediments, tree rings, and fossil corals, shows that the earth's climate has varied significantly over timescales from months to millennia. Most studies of global climate patterns conclude that the global climate changed rapidly during the twentieth century and that the speed of these changes exceeds that of most previous fluctuations (USGCRP 2003, Houghton et al. 2001, Mann et al. 1999). Global surface temperatures, in particular, have risen by 0.6 ± 0.2 ºC over the past century (Houghton et al. 2001).

The expected continuation of global climate change will inevitably lead to significant alterations of Great Lakes regional climate. Changing regional climate will, in turn, have a tremendous effect on natural systems in the Great Lakes region (Sousounis and Bisanz 2000). It is imperative that the Network has climate monitoring systems in place to detect and characterize regional climate change. We can then test for associations between climate data and other Vital Signs.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Specific monitoring questions

- How does the climate of the western Great Lakes region vary at different spatial and temporal scales?
- How is climate change associated with park natural resources and the dynamics of other Vital Signs?
- Has the climate of the western Great Lakes region changed significantly from that of past decades or past centuries?

Specific monitoring objectives and justifications

1. Measure precipitation and air temperature in all GLKN parks and surrounding areas. *Justification:* This objective will provide baseline data and continuously updated data sets to facilitate the detection of regional climatic change and concomitant effects on

natural systems in the western Great Lakes ecosystem as a whole. Precipitation and temperature exert strong controls over almost all physical and ecological processes in the GLKN.

2**.** Measure secondary climatic elements including wind speed/direction, relative humidity, snow depth, soil temperatures and incoming solar radiation in the GLKN parks. *Justification:* These secondary climatic elements will complement information on temperature and precipitation gathered under Objective 1, and often are more directly tied to ecological factors than surface air temperature and precipitation. For example, although surface air temperatures during the winter may directly determine a potential vegetation community, the interplay between temperature, radiation, and precipitation may have a large impact on ungulate populations and vegetation due to snow depth (Post and Stenseth 1999).

Basic Approach:

Existing networks of climate monitoring stations are maintained by a variety of state and federal agencies, some of which have operated for over 100 years. The two primary federal programs that have stations important for assessing park climates are the NOAA NERON (NOAA's Environmental Real-time Observation Network; formerly the Cooperative Observer Network - COOP) and the interagency RAWS (Remote Automated Weather Stations) network. State efforts, such as those related to surface transportation and agriculture, also have stations that contribute to climate monitoring in Network parks.

Protocol development has focused on determining (1) if the existing weather stations provide adequate sampling of spatial and temporal variability in the GLKN climate, and (2) how best to address shortfalls in the current system. There are some known gaps in the existing coverage of weather stations and the Network has funded up-grades to two RAWS at ISRO. We anticipate that additional sites at ISRO and other parks may be desirable. Priority for any additional weather stations is through a cooperative partnership with an existing climatic monitoring program (e.g., NOAA's NERON) which will allow us to share costs and capitalize on existing standards and data processing infrastructures.

Field methodology

Most of the field collection of weather data is automated; however, measurement of snowfall and snow depth at some stations and station maintenance will be required. To the extent possible, the Network will use stations that are part of existing weather monitoring programs, and station maintenance and initial data processing will not be performed by GLKN. If the weather stations are within a park boundary, park personnel may have some responsibility for site or station maintenance. The set of parameters measured is usually determined by the primary agency responsible for a station; however, GLKN will make an effort to included additional parameters at park-based stations, if possible.

Data analysis and reporting

Data from the various climate monitoring programs are acquired from web-based program archives. Procedures for downloading these data will be described in standard operating procedures (SOPs). An annual report will be prepared by the Network and will include summarized data, calculated standard indices, identification of extreme conditions, and comparisons with historical conditions. Trend analyses will be performed every five years and may include the entire period of record or the rolling thirty-year period standard for climatic analyses.

Climate monitoring involves several programs funded by non-NPS agencies. The GLKN protocol is based on the assumption that these programs will continue to be externally funded. The Network does not plan to spend a great deal on climate monitoring in the Network parks; however, small expenditures to supplement monitoring by external programs may be desirable. The workload for GLKN staff will primarily consist of retrieving, archiving, and analyzing data, and report preparation.

Principal Investigators and NPS Lead:

The NPS lead within the GLKN is Mark Hart. A memorandum of understanding (MOU) with NOAA is pending.

Development Schedule, Budget, and Expected Interim Products:

We are currently finalizing an MOU with NOAA. The database for this protocol will be developed during 2006 and full implementation will occur in 2007.

Acknowledgments

Portions of this PDS were adopted, with minor changes, from Greater Yellowstone Network.

Literature Cited:

Bonan, G. B. 2002. Ecological Climatology: Concepts and Applications. Cambridge: Cambridge University Press, New York.

Gucciardo, S., B. Route, and J. Elias. 2004. Conceptual models for long-term ecological monitoring in the Great Lakes Network. Great Lakes Inventory and Monitoring Network Report GLKN/2004/04.

Houghton, J. T., Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, X. Dai, K. Maskell, and C. A. Johnson, editors. 2001. Climate change 2001: The scientific basis. Cambridge University Press, New York.

Mann, M. E., R. S. Bradley, and M. K. Hughes. 1999. Northern hemisphere temperatures during the past millennium: inferences, uncertainties, and limitations. Geophysical Research Letters **26**:759-762.

Moran, J. M., and E. J. Hopkins. 2002. Wisconsin's weather and climate. University of Wisconsin Press, Madison.

Post, E., and N. C. Stenseth. 1999. Climatic variability, plant phenology, and northern ungulates. Ecology **80**(4):1322-1339.

Sousounis, P. J., and J. M. Bisanz. 2000. Preparing for a changing climate: the potential consequences of climate variability and change: Great Lakes. Great Lakes Regional Assessment Group. University of Michigan, Ann Arbor.

USGCRP (U.S. Global Change Research Program). 2003. Strategic plan for the U.S. climate change science program. Washington, D.C.: NOAA-Climate Change Science Program.

PROTOCOL DEVELOPMENT SUMMARY – AIR QUALITY

Protocol: Air quality monitoring protocol for the Great Lakes Network [short name: air quality]

Parks Where Protocol will be Implemented: APIS, GRPO, INDU, ISRO, MISS, PIRO, SACN, SLBE, VOYA.

Justification/Issues Being Addressed:

Air quality was ranked as the twelfth highest priority Vital Sign for the Network. Air resources in the national parks fall under both the Clean Air Act and the NPS Organic Act. Isle Royale and Voyageurs National Parks (NP) are designated Class I air quality areas while the other seven Network parks are located in Class II air quality areas.

Atmospheric deposition can significantly impact aquatic resources. The nine parks within the Great Lakes Network represent the major freshwater ecosystems within the central North American continent, encompassing headwaters that flow toward Hudson Bay, the Mississippi River basin, and the Great Lakes system. As such, all GLKN parks have aquatic ecosystems as a primary element underlying their establishment as national parks.

Indiana Dunes National Lakeshore, and Isle Royale and Voyageurs National Parks have on-site ambient air quality monitoring, while the other six parks in the Network have ambient monitoring stations nearby. The air pollutants of greatest concern for the GLKN are mercury, other metals, and organics. In addition, both Indiana Dunes and part of Sleeping Bear Dunes National Lakeshores are in proposed 8-hour ozone non-attainment areas. An ozone injury risk assessment indicates that the risk of injury is moderate to high in Indiana Dunes, Pictured Rocks, and Sleeping Bear Dunes National Lakeshores. Sulfur and nitrate deposition are also significant pollutants in the upper midwest region, contributing to acidification, particularly in nutrient-poor ecosystems with little buffering capacity. These pollutants can alter pH in water and soils, affecting integrity and stability of biological systems (Maniero and Pohlman 2003).

The Great Lakes Network will not conduct air quality monitoring in Network parks, but will acquire data on a regular basis from NPS-Air Resources Division (ARD), EPA, other state pollution control agencies, and local organizations. The GLKN will adopt the protocols developed by these cooperative efforts, and will acquire, archive, analyze, and report on the data. Currently, NPS-ARD has developed formal protocols for wet deposition and ozone, available at:

www2.nature.nps.gov/air/Monitoring/docs/200508FinalWetDepProtocol.pdf

www2.nature.nps.gov/air/Monitoring/docs/FinalOzoneProtocol.pdf

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

- How does the deposition of target airborne contaminants change through time?
- What are the changes in air quality through time and how do parks compare across the Network?

- How is the quality of the air linked to ecosystem quality? What are the trends? How does it affect rare vegetation?
- What are air quality trends and status? What are the impacts of air quality on other ecosystem components and processes? What is the significance of airborne contaminants?

Basic Approach:

Sampling design

Air quality monitoring data will result from point samples, not from a survey or experimental design. Although rigorous criteria are used in selecting sites for monitoring, these have largely to do with avoiding close proximity to sources of pollutants and other issues related to interference with obtaining accurate measurements. Site selection is based on national program objectives, which generally attempt to obtain regionally representative samples, rather than an inferential sampling design.

Field methodology

Most of the field collection of air quality samples and data is automated, the principal exceptions being the changing of sample collectors (filters, buckets). Field operations consist of weekly visits for inspection, routine maintenance, and sample collection by park staff, and semi-annual to annual maintenance by program specialists.

Data analysis and reporting

Data from the various air quality monitoring programs will be acquired from web-based program archives. Procedures for downloading these data will be described in standard operating procedures (SOPs). An annual report will include summarized data, calculated standard indices, identification of extreme conditions, and comparisons with historical conditions.

Trend analyses will be performed every five years and may include the entire period of record, as well as rolling five year periods. Procedures will include regression (ozone, visibility), multiple regression or other covariance techniques (wet and dry deposition with precipitation as a covariate), and appropriate comparisons of means across years. Analyses of visibility data will employ data summarized using procedures following EPA regional haze guidance.

Evaluation of visibility data will include discussion of compliance with Regional Haze Guidelines for Class I areas; that is, improvement for the most impaired (20% worst) days and no degradation for the least impaired (20% best) days, from a baseline represented by 2000 to 2004.

Air quality monitoring involves several ongoing programs. The GLKN protocol is based on the assumption that the programs will continue to be externally funded. The Network does not plan to fund additional air quality monitoring in the park units. The workload for GLKN staff will consist of retrieving, archiving, and analyzing data, and report preparation.

Principal Investigators and NPS Lead:

Ulf Gafvert, GIS Specialist for the Network, will be responsible for acquiring air resource data and preparing summary reports. David Pohlman, Midwest Region Air Quality Specialist, will be involved in analysis of the data.

Development Schedule, Budget, and Expected Interim Products:

A full protocol for air quality monitoring protocol will be developed in 2006, with database development in 2007, and implementation in 2008. The Network does not plan to conduct air quality monitoring beyond what is already in place through the NPS-ARD and existing programs. Funding for this program is uncertain, but needs are expected to be minimal. We anticipate NPS staff time will be dedicated to acquiring, analyzing, and reporting data gathered from the National programs.

Acknowledgments:

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Literature Cited:

Maniero, T. and D. Pohlman. 2003. Air quality monitoring considerations for the Great Lakes Network parks. Great Lakes Inventory and Monitoring Network Report GLKN/2003/06.